Solar Salt Production at Exportadora de Sal

Juan I. Bremer G.
Exportadora de Sal,
S. A. de C. V. Guerrero Negro, B.C.S., México

ABSTRACT

Exportadora de Sal, one of the largest solar salt plants in operation, is located on the Pacific side of the Peninsula of Baja California in Mexico. It initiated operations in 1954 and at present its production capacity well exceeds six million metric tons per year and continues to expand. Not only has Exportadora de Sal grown continuously from 80,000 tons exports in 1957 to over 5,000,000 tons at present, but it has also developed basic methods to maintain and increase its salt quality. These methods throughout the years have been used and improved to produce salt with low contents of impurities, such as calcium, magnesium, sulphates and insoluble matter, making the company one of the highest quality salt producers in the world.

INTRODUCTION

Guerrero Negro salt fields are located on the Pacific Coast of the Peninsula of Baja California, approximately 730 km south of San Diego, Cal; on the 28th Parallel, bordering the lagoons of "Ojo de Liebre" and "Guerrero Negro," commonly known as Scammons and Black Warrier Lagoon. With sea water from laguna "Ojo de Liebre", constant northwest wind, low precipitation, abundant sunlight and impermeable natural tidal flats, the area provides ideal conditions for solar salt production.

Construction of the salt fields began in 1954 and the company's first salt shipment, of 16,842 MT, in June of 1957 went to the West Coast of the United States. Since that date, and up to December 31, 1982, the company has exported 77,465,894 MT of solar salt to many different countries throughout the world, mainly to Japan, the United States and Canada.

To maintain a 5-million-metric-ton annual production for the last 5 years, with a record export of 5,725,302 MT in 1980, the company has had to construct 13 concentrating ponds covering a surface of over 20,000 hectares; 45 crystallizing ponds for a total of 3,000 hectares (at present only utilizing 2,000 hectares); 175 km of dividing dikes; 45 km of channels; and over 200 km of roads.

Besides having constructed these installations, Exportadora de Sal has designed and constructed a washing plant; a deep-sea port to load ships, with a guaranteed draft of 60 feet, stockpile facilities to hold over one million tons of salt, power plants, maintenance shops, housing for its workers, schools, hospitals, recreation centers, and company stores. All this has given origin to the towns of Guerrero Negro, with over 5,000 people, and its export facilities on Cedros Island with approximately 680 people.

The company's salt transport fleet (from crystallizing ponds to wash plant) is considered one of the world's largest unit hauls on a continuous basis (360 metric tons per tractor with three trailers). Our washing system has a capacity of 1800 MT per hour, taking into consideration that our harvested salt from crystallizers with a salt base would be of the highest quality. The company also operates its own tug and barge transportation company capable of moving approximately 20,000 MT of salt daily from Guerrero Negro to Cedros Island, where it is stockpiled and allowed to drain. The fleet consists of five tugs and seven barges, each barge having a capacity of 6,800 MT. On Cedros Island the port facilities have a loading capacity of 3,000 MT per hour and can accommodate vessels with a load capacity of 5,000 to 156,000 MT.

Besides the effort of producing 5 million tons of salt per year on a continuous basis and at present developing additional concentration area to generate more saturated brine for future crystallizing ponds, permitting salt floor maintenance continuously in existing crystallizers, the company has developed its own methods of control so as to maintain high quality salt.

PRODUCTION

Concentration Area.

Production begins in Guerrero Negro at its seawater pumping station, which is located at the extreme end of "Scammons" lagoon, where water is introduced through ten 48-inch-diameter pumps (35,000 GPM each). Water is pumped into the first of a series of 13 concentrators through which the brine continuously flows by gravity throughout the year. The seawater concentration at the pumping station has a density of 4.5° Bé (specific gravity 1.032), one degree higher than the seawater at the entrance of the lagoon. This increase in density is due to the lagoon's surface of 500 km^2 and shallow depth, which acts as pre-concentrator. The ratio between concentrating and crystallizing ponds at Exportadora de Sal is less than other solar salt fields because of the higher density intake brine. After concentration, at the end of pond 13, we obtain a 26° Bé (specific gravity 1.297) brine and, depending on its chemical composition, it is allowed into the crystallizing ponds. This is one of the most important control points to ensure high quality salt and maximum production. In 1982 we pumped 461 million m^3 of seawater. This volume was calculated by using average evaporation, the acreage of concentration area, and assuming a 15% loss of brine due to seepage. The volume of saturated brine at 26° Bé, fed to crystallizers was 40 million m^3. (See Material Balance chart).

Throughout the last concentration ponds we annually crystallize approximately 600,000 MT of calcium sulfate, and in the last of the concentrators we produce approximately 1.8 million tons of salt. The salt is allowed to crystallize in this area for one purpose, to ensure a high quality brine to all crystallizing ponds. Below I will explain the process used to recuperate this salt.

The depth of brine in the concentrating area is approximately one meter in pond No. 1 and one half meter in pond No. 13. Through the concentrating ponds the brine travels a distance of 70 km during a period of approximately 15 months. The main factors that determine the efficiency of our concentrating system are as follows:

1. "Scammon" lagoon, which serves as a natural pre-concentrator, increases density from 3.5 to 4.5° Bé, allowing a reduction of 26% in pumping, and of 15% in concentrating pond area.
2. The tidal flats where the concentrating ponds are constructed, being perfectly level, permit brine flow by gravity throughout the system, thereby reducing pumping cost.
3. The concentrating ponds are almost totally impermeable due to a well balanced biological system that permitted the formation of algal mats throughout 45% of the concentrating ponds, which are adjacent to the lagoon, eliminating filtrations. In addition, 20% of the area is sealed by calcium sulfate layers that have crystallized over the years. Also, in the subsoil there is fine silty material throughout the concentrators.
4. Evaporation in the concentration area is greatly assisted by the dark coloration of the algal mats on the bottom of our ponds which permit retention of solar rays and an increase in brine temperature. Also, constant winds throughout the year help increase evaporation. (See graph #1 which relates brine evaporation (°Bé) vs fresh water evaporation).
5. Another important factor in our evaporation is low rainfall. Throughout the 25 years of weather records Exportadora salt fields has had an annual average precipitation of approximately 3 inches. (See graph # 2, Rain at Guerrero Negro 1957–1982).
6. All dikes in concentrating ponds have been riprapped with rock to avoid erosion by wave action.
7. Below we give the chemical composition of seawater entering "Scammons" lagoon, seawater pumped to the concentrating ponds, and a normal brine fed to the crystallizing ponds.

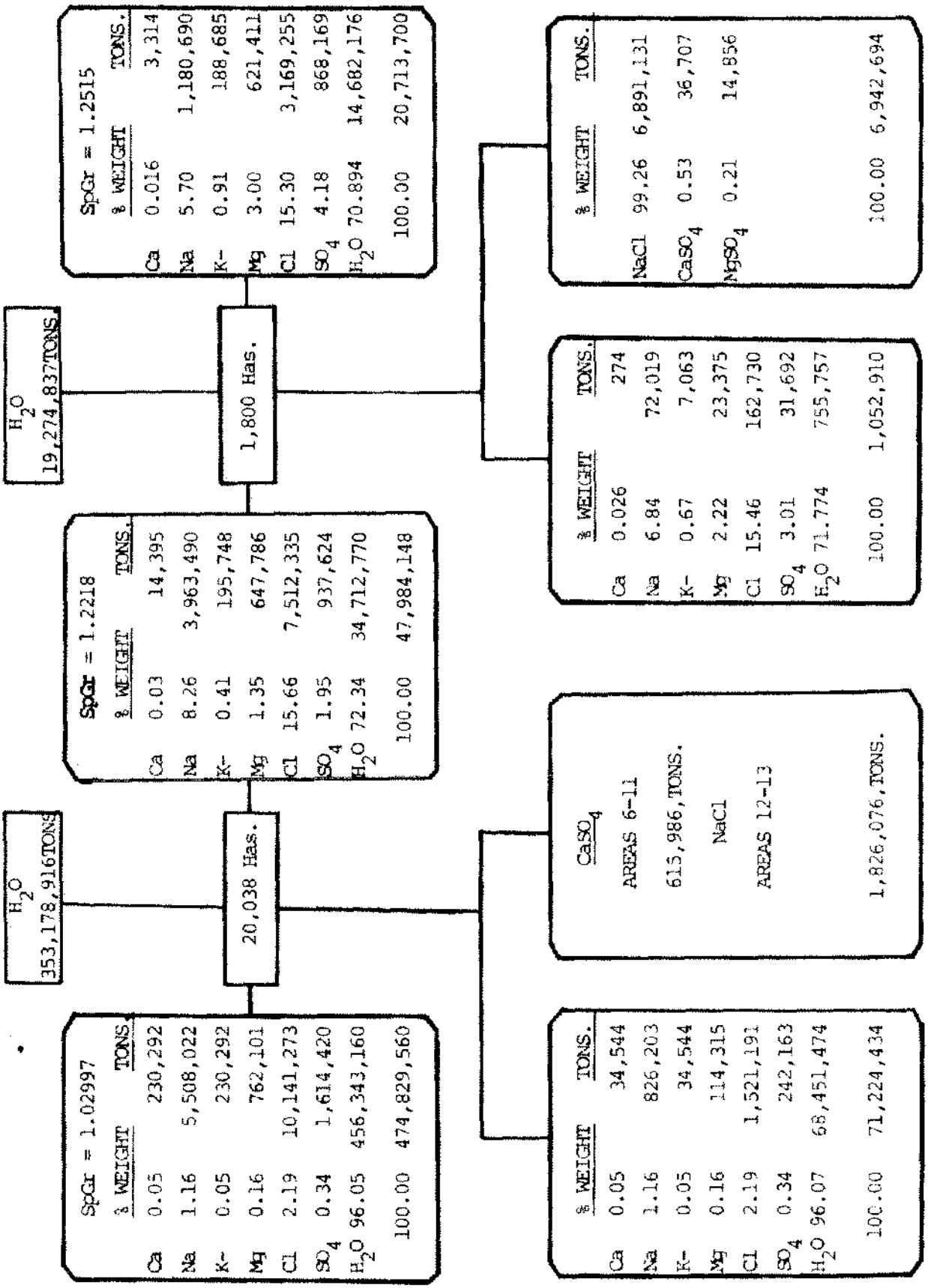
Chemical Composition of Brines

	Seawater to Lagoon % by Wt.	Seawater to Concentrators % by Wt.	Brine to Crystallizers % by Wt.
Ca	0.04	0.05	0.03
Mg	0.12	0.16	1.35
Na	1.06	1.16	8.26
K	0.04	0.05	0.41
Cl	1.90	2.19	15.66
SO_4	0.27	0.34	1.95
H_2O	96.57	96.05	72.34

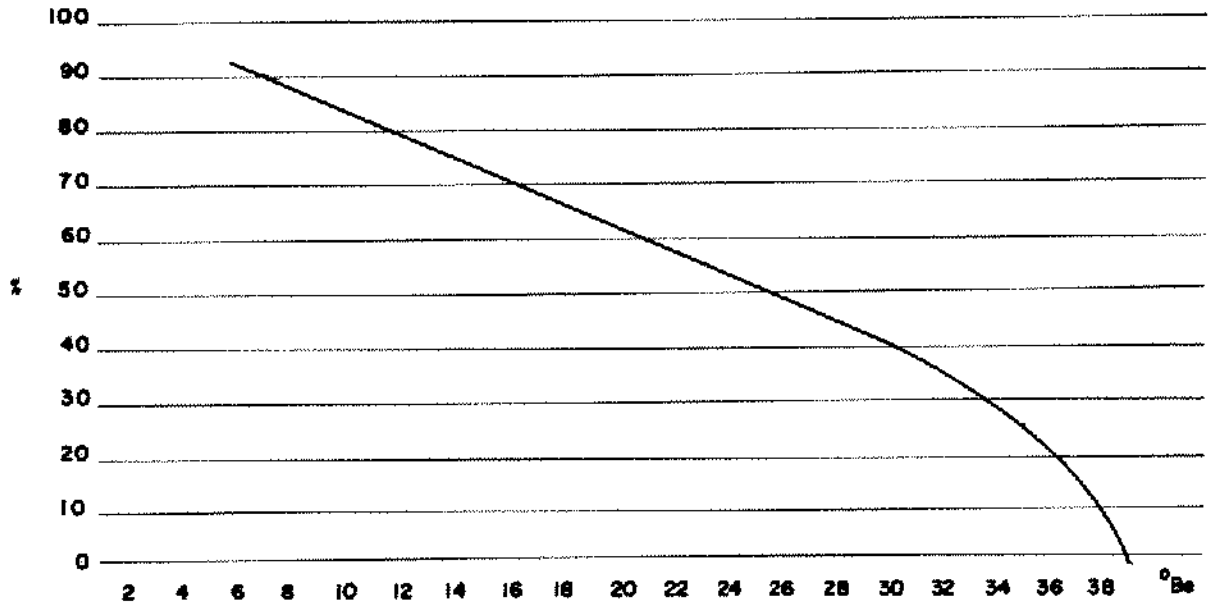
CRYSTALLIZING AREA

Saturated brine with a maximum Ca content of 0.03% and a minimum Mg content of 1.20% is fed simultaneously to different rows of crystallizing ponds. This flow is maintained throughout the year at a defined depth. When the brine in the last pond reaches approximately 29° Bé or 3.00% Mg, it is discharged to a bittern channel and pumped to a designated area. After approximately 8 months of brine flowing continuously through each pond, the pond is drained and ready for harvest (approximately 6" of salt). First the salt is scarified and windrowed. Then, with a specially designed salt harvesting machine, the salt is loaded into large trailers and taken to the washing plant.

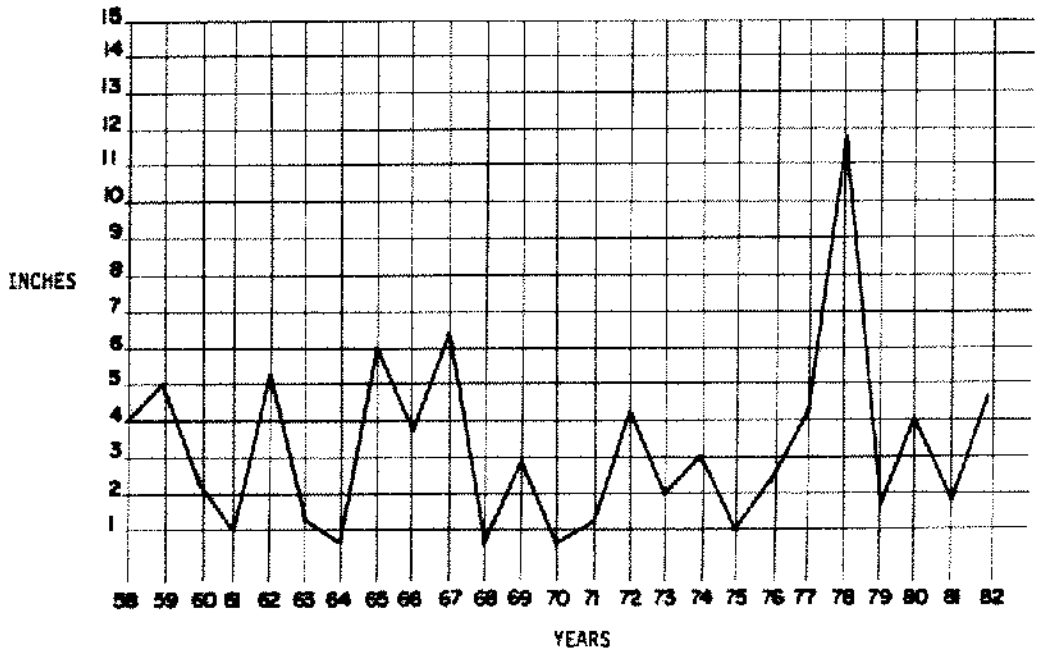
We calculate our salt production in each pond utilizing a graph that we designed after many years, taking into


MATERIAL BALANCE
H2O 353,178,916TONS
20,038 Has.
SpGr = 1.02997
% WEIGHT TONS.
Ca 0.05 230,292
Na 1.16 5,508,022
K- 0.05 230,292
Mg 0.16 762,101
Cl 2.19 10,141,273
SO4 0.34 1,614,420
H2O 96.05 456,343,160
100.00 474,829,560
SpGr = 1.2218
% WEIGHT TONS.
Ca 0.03 14,395
Na 8.26 3,963,490
K- 0.41 195,748
Mg 1.35 647,786
Cl 15.66 7,512,335
SO4 1.95 937,624
H2O 72.34 34,712,770
100.00 47,984,148
H2O 19,274,837TONS
1,800 Has.
SpGr = 1.2515
% WEIGHT TONS.
Ca 0.016 3,314
Na 5.70 1,180,690
K- 0.91 188,685
Mg 3.00 621,411
Cl 15.30 3,169,255
SO4 4.18 868,169
H2O 70.894 14,682,176
100.00 20,713,700
CaSO4
AREAS 6-11
615,986,TONS.
NaCl
AREAS 12-13
1,826,076,TONS.
% WEIGHT TONS.
Ca 0.05 34,544
Na 1.16 826,203
K- 0.05 34,544
Mg 0.16 114,315
Cl 2.19 1,521,191
SO4 0.34 242,163
H2O 96.07 68,451,474
100.00 71,224,434
% WEIGHT TONS.
Ca 0.026 274
Na 6.84 72,019
K- 0.67 7,063
Mg 2.22 23,375
Cl 15.46 162,730
SO4 3.01 31,692
H2O 71.774 755,757
100.00 1,052,910
% WEIGHT TONS.
NaCl 99.26 6,891,131
CaSO4 0.53 36,707
MgSO4 0.21 14,856
100.00 6,942,694

GRAPH # 1



GRAPH # 2



consideration laboratory and field studies involving average brine densities of many ponds, fresh water evaporation during the crystallization period, and brine chemical composition. Calculation from this graph has an accuracy of ±5%. Research is continuing in order to increase the accuracy of the production figure read directly from the graph. Salt produced in metric tons per hectare of a given crystallizer can be read directly from the graph for each centimeter of fresh water evaporated during this production period. (See graph #3) The main factors that determine the efficiency of our crystallizing ponds are the following:

1. A continuous brine flow through each pond maintains constant concentrations and establishes a gradient density, avoiding mixing brines with different chemical composition. This practice helps produce a larger and purer salt crystal.
2. Well-leveled pond floors permit a better flow and equal depth of brine throughout the ponds, and also simplifies draining of the crystallizers before harvest.
3. All dividing dikes between crystallizers are constructed with the proper seal between ponds to avoid brine seepage, especially when a pond is emptied for harvest.
4. Brines with density between 26 and 29° Bé are populated by halophilic-halobacteria. that give the brine a pink color, which helps in retention of solar rays and increases temperature and evaporation.

An average analysis of the salt produced in our crystallizers (before washing) is as follows:

	Percent By Weight
NaCl	98.54
Ca	0.16
Mg	0.20
SO_4	0.68
Ins.	0.07

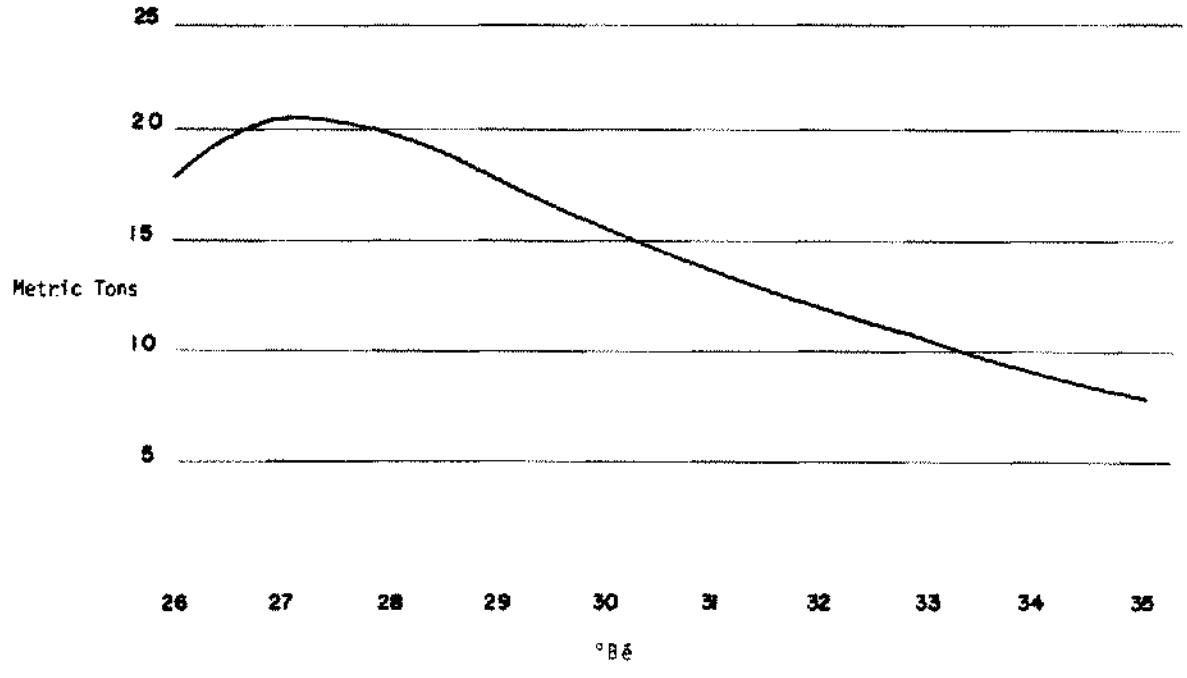
SALT QUALITY CONTROL

It is well known by most salt producers that the worldwide chemical industry (mainly caustic and chlorine producers) is demanding a higher quality product. Exportadora de Sal has had to develop quality control methods that will guarantee high purity salt.

Determining factors in producing high quality salt:

1. NaCl begins to crystallize at 25.6° Bé, but salt produced between 25.6 and 26.0° Bé is relatively high in $CaSO_4$ and difficult to eliminate. As mentioned previously, we crystallize this salt in our final concentrating pond (approx. 1.8 million tons/year). During the winter months when we have lower evaporation and less brine demand for our crystallizing system, we dissolve the salt by flowing 9° Bé brine through this concentrating pond, producing a 22° Bé brine, which is returned to the main concentrating area.

GRAPH # 3



This 22° Bé brine has an NaCl content higher than normal and produces a high purity salt.

2. Brine level in crystallizers is maintained between 40 and 50 cm to ensure a minimum differential in temperature and avoid fine salt crystals, also dike erosion and seepage to other ponds, mainly the pond being harvested. Low levels can cause difficulty in controlling density, due to rapid evaporation.
3. Continuous brine flow through each pond helps to maintain constant brine composition and produce a large crystal easy to wash.
4. Level pond floors maintain equal brine depth, producing a uniform product throughout the crystallizer.
5. Impermeable dikes and floors eliminate filtration and contamination of salt with insoluble matter.
6. After each harvest the pond should be perfectly cleaned and leveled to guarantee best results during the next harvest.
7. Approximately 15 days after filling a pond with brine (after harvest and clean-up), it is necessary to split this pond and interrupt crystal growth by forming a cleavage point that separates the salt floor from the new layer to be produced. This permits easy removal during the next harvest.
8. Salt washing to remove impurities such as Ca, Mg, SO_4 and insoluble matter is a very necessary operation to obtain the quality demanded by our customers. In our washing operations we increase the salt purity from 98.54% to an average of 99.70% NaCl (dry basis).
9. Stockpile time is important to permit drainage of excess moisture (brine), which removes additional Mg and SO_4 contaminants and also ensures a dryer salt to the customer.